Renewable and Sustainable Energy Reviews 15 (2011) 4652–4658

Contents lists available at SciVerse ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

A review on energy scenario and sustainable energy in Iran

M. Mohammadnejad [a], M. Ghazvini [a], T.M.I. Mahlia [a,b,*], A. Andriyana [a]

[a] Department of Mechanical Engineering, University of Malaya, 50603 Kuala Lumpur, Malaysia
[b] Department of Mechanical Engineering, Syiah Kuala University, Banda Aceh 23111, Indonesia

ARTICLE INFO

Article history:
Received 22 February 2011
Accepted 5 July 2011
Available online 18 September 2011

Keywords:
Renewable energy
Energy scenario
Sustainable energy
Fossil fuel
Wind energy
Solar energy

ABSTRACT

Energy has a key role in social-economic development of countries. Fossil fuels which have a large contribution in energy consumption in the world, are depleting and it seems necessary to find alternative energy sources. Today, energy consumption in Iran is increasing due to population growth and economic development. This study presents an overview of the energy resources, supply and demand as the current energy scenario in Iran. Also, this study discusses other kinds of energy especially renewable energy such as wind, solar, biomass and geothermal as the alternative for energy supply in this country. It is found that, since the country has many windy areas and at least 2800 sunshine hours per year, it has high potential for utilizing wind and solar energy. Therefore, Iran must try to optimize energy consumption especially in the residential sector and increase the contribution of renewable energy in energy supply to make the energy mix secure and environmentally sustainable.

Contents

1. Introduction

Nowadays energy has a key role in social-economic development of countries. World population growth beside economic development has increased energy consumption. The energy consumption was increasing from 6630 million tons of oil equivalent (Mtoe) in 1980 to 11,295 Mtoe in 2008 worldwide as presented in Table 1 [1]. This shows that the rate of energy consumption has been increased rapidly in recent years. It is estimated that the crude oil and natural gas reserves will be depleted in the next 41.8 and 60.3 years respectively [2].

Energy generation from fossil fuels is one of the important cause of greenhouse gas emissions and climate change. In order to control these effects, many methods have been suggested by scientists and researchers such as optimizing of energy consumption and using renewable energy sources [3–13]. These methods are currently used by developed countries and it seems that the renewable energy will be the main energy sources for the world in the future.

The emission of carbon dioxide which is the major courses of greenhouse gas has increased significantly. Fig. 1 shows the global total carbon dioxide emission from 1960 to 2008 [14]. The depleting

* Corresponding author at: Department of Mechanical Engineering, University of Malaya, 50603 Kuala Lumpur, Malaysia. Tel.: +60 3 7967 5385; fax: +60 3 7967 5317.
E-mail addresses: indra@um.edu.my, i_mahlia@hotmail.com (T.M.I. Mahlia).

1364-0321/$ – see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.rser.2011.07.087

Table 1
Global primary energy consumption [1].

Source	1980		2008	
	Mtoe	Share (%)	Mtoe	Share (%)
Petroleum	2979.80	44.9	3927.90	34.8
Coal	1807.90	27.3	3303.70	29.2
Natural gas	1296.80	19.6	2726.10	24.1
Nuclear	161	2.4	619.70	5.5
Hydropower	384.3	5.8	717.50	6.4
Total	6629.80	100	11294.90	100

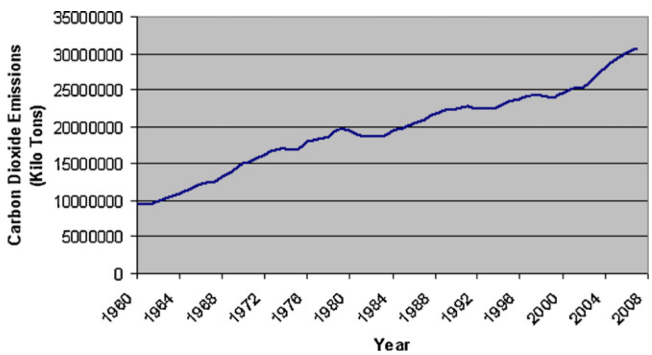


Fig. 1. Global total carbon dioxide emission [14].

of fossil fuels reserves and the adverse effects of greenhouse gas emission on the climate are two factors that indicate the necessity of increasing the contribution of renewable and sustainable energy in energy consumption in Iran. Moreover, diversification of various energy resources is important in the power sector in Iran.

This study presents an overview of the energy reserves, supply and demand and current energy scenario in Iran. The status of the renewable energy usage has also been discussed. The potential of utilizing renewable energy from wind, solar, biomass and geothermal as new sources of energy for Iran for the future has been explored. Besides that, the most up-to-date data of energy scenario in Iran has been used for this study. The work on sustainable energy, energy efficiency and renewable energy in some other developing countries can be found in Refs. [15–40].

2. Iran energy scenario

Iran is located in southwest of Asia with about 1,648,195 km^2 area. The population of Iran has increased from 61.83 million in 1998 to 71.74 million in 2008 [41]. Iran GDP increased with an average rate over 5.5% from 1998 to 2008. Fig. 2 shows the GDP by type of activity from 1998 to 2008 in Iran.

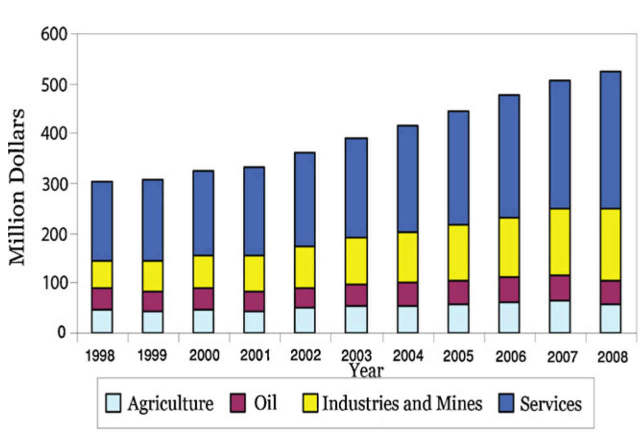


Fig. 2. The GDP by type of activity in Iran [43].

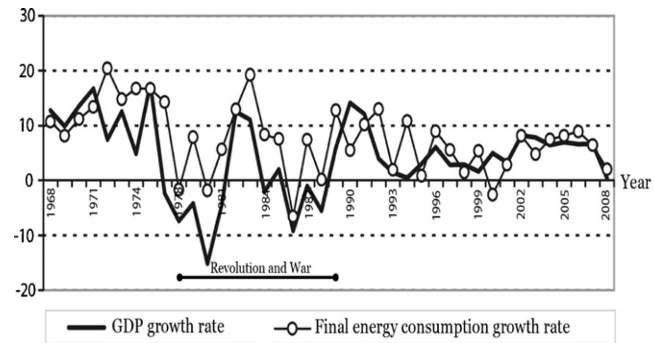


Fig. 3. The GDP and final energy consumption growth rate [44].

Like many developing countries, industrialization in Iran has effects on increasing energy consumption in the nation. Fig. 3 shows the changes of GDP growth and final energy consumption in the country from 1969 to 2008 [42,43].

It is estimated that the total primary energy supply reaches 1493.21 million barrels of oil equivalent in 2008. This is more than 59.9% increase from 2001 and it is considered high for developing countries. Fig. 4 shows the primary energy supply by fuel type in Iran [44].

Due to industrialization the final energy consumption has risen in the past decade in Iran. The final energy consumption has increased at an annual growth rate of 6.4% from 636.3 Mboe in 1998 to 1187.4 Mboe in 2008 [43]. Fig. 5 shows the final energy consumption by sector in Iran from 1998 to 2008.

Fig. 5 also indicates that the residential and commercial sector is the major energy consumption with 417.5 Mboe in 2008 and it is followed closely by the transportation sector. The energy consumption by residential and commercial sector has decreased in 2007 and 2008. The amount of energy consumption in the industry has increased continuously with a record of 254.8 Mboe in 2008 [44].

Iranian energy sector is largely depends on the crude oil and natural gas. Due to decreasing fossil fuel resources, the government has decided to control and reduce the energy consumption especially by residential and commercial sectors. The usage other types of energy specially renewable energy has received great attention from Iran government in recent years [45]. The contribution of crude oil in energy supply in Iran has decreased from 54.03% in 2001 to 44.02% in 2008. On the other hand, the contribution of natural gas in energy supply has risen from 44.63% in 2001 to 54.93% in 2008. The contribution of the other energy resources such as coal, biomass, hydropower, wind and solar energy is only 1%, which is very low in comparison with the other countries [44]. Due to

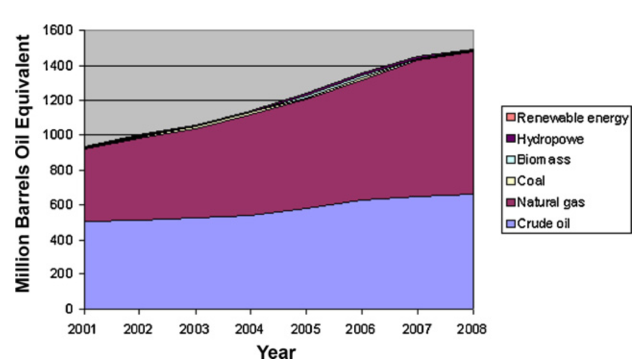


Fig. 4. The primary energy supply by fuel type in Iran [44].

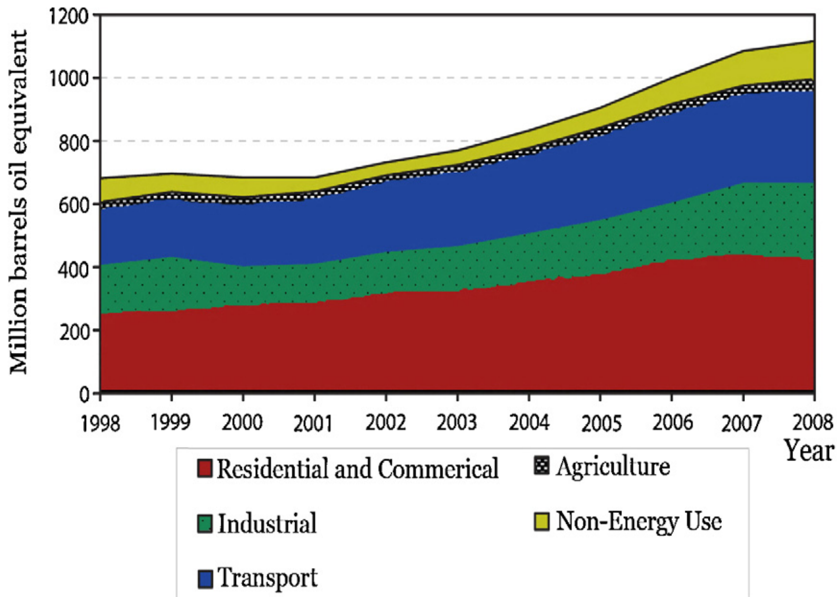


Fig. 5. Final energy consumption by sector [44].

Table 2
Amount of oil and condensate reserves in Iran (unit: billion barrels) [43].

Location		Total reserve	Cumulative production up to 2008	Affordable reserve up to 2008
Offshore	Crude oil	144.59	57.9	86.7
	Condensate	22.95	6.38	16.57
	Total	167.45	64.28	103.27
Onshore	Crude oil	20.48	6.79	13.69
	Condensate	20.87	0.82	20.05
	Total	41.35	7.6	33.74
Total		208.89	71.88	137.01

environmental consequences of burning fossil fuels such as greenhouse gas emissions [46] and the fact that the fossil fuel resources will be depleted 1 day, the dependency of Iran energy scenario to fossil fuels will have an adverse effect on the economy in Iran. Therefore, action toward using renewable energy resources should be put as a priority by the government.

3. Energy mix in Iran

Energy mix in Iran, consist five main resources which are crude oil, natural gas, coal, hydro and renewable energy. However, Iran is trying hard to increase the contribution of renewable energy supply. On the other hand, Iran has developed nuclear technology and will be using nuclear as energy sources in the near future.

3.1. Crude oil

Iran is the fourth largest oil producer of the world. As it can be seen in Table 2 the total amount of oil and condensate reserves in Iran is estimated about 208.89 billion barrels in 2008 with 80.2% is offshore and 19.8% is onshore [43].

The estimated amount of affordable reserves oil up to end of 2008 is 137.01 billion barrels that shows 0.4% decrease compare to 2007 [44]. The number of active oil fields in Iran is 96 which 62, 16, 18 of these fields are offshore, onshore and shared with neighborhood countries respectively [43]. The production of crude oil in Iran is performed by four national companies and the total amount of production of crude oil is 4.01 million barrels per day as shown in Table 3 [43].

Table 3
The production of crude oil by national companies [43].

Oil company	Thousand barrels per day
Manateghe Naftkhize Jonoob (offshore)	3075.24
Manateghe Markazi (offshore)	151.03
Arvandan (offshore)	83.6
Falate Ghare Iran (onshore)	706.65

There are nine active oil refineries in Iran, with a total production of 1.42 million barrels per day, as shown in Table 4. The largest refinery capacity is 350 thousand barrels per day by Abadan refinery [44].

This refinery capacity is not enough for the country demand and Iran has become an importer of petroleum. In order to solve this problem Iran has recently invested in refinery activities for constructing new refineries.

Table 4
Active oil refineries in Iran [44].

Refinery	Capacity (thousand barrels per day)
Abadan	350
Esfahan	200
Arak	150
Tehran	220
Bandar Abbas	320
Tabriz	110
Kermanshah	15
Shiraz	40
Lavan	20
Total	1425

Table 5
Natural gas reserves in Iran (unit: trillion cubic meter) [43].

Location	Total reserves	Cumulative production up to 2008	Affordable reserve up to 2008
Onshore	20.26	0.44	19.82
Offshore	11.89	2.71	9.18
Total	32.15	3.15	29

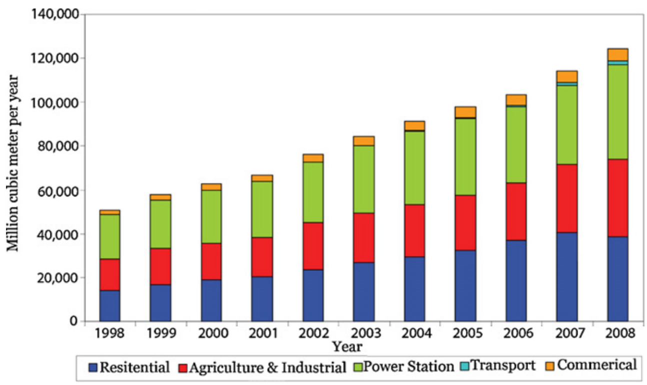


Fig. 6. Natural gas consumption by sector [43].

3.2. Natural gas

The estimated amount of natural gas reserves in Iran is about 29 trillion cubic meter (approximately 19.7% of the world natural gas reserves) which ranks Iran first in Middle East and second in the world [47]. Table 5 shows natural gas reserves in Iran up to end of 2008 [43].

In the past 8 years the production of natural gas has risen from 312.23 million cubic meters per day in 2001 to 551.89 million cubic meter per day in 2008. Beside this, domestic natural gas consumption has increased with an annual rate of 9.4% to 124,256 million cubic meters in 2008 [43]. There are six LNG processing plans in Iran which are supplied by Parse Jonoobi filed. The largest plan of LNG production in Iran is Persian-LNG with total liquefaction capacity of 22.3 million tons per year [44]. As it can be seen in Fig. 6 the major contributor of natural gas consumption is residential which is followed by industrial and power station [43].

3.3. Coal

Coal is an important resource in the energy mix in some countries like USA and China, but it only contributes 0.21% of the energy mix in Iran as presented in Table 6 [43]. The total production of coal in Iran is estimated 2.73 million tons in 2008 and the most amount of coal is produced by mines in Kerman and Yazd which

Table 6
The amount of energy supply by coal and contribution of coal in energy mix in Iran [43].

Year	Energy supply by coal (Mboe)	Contribution of coal in energy supply (%)
1998	4.79	0.23
1999	4.44	0.21
2000	4.36	0.2
2001	4.26	0.2
2002	4.58	0.21
2003	4.39	0.18
2004	3.9	0.15
2005	6.5	0.25
2006	9.44	0.35
2007	9.44	0.33
2008	6.13	0.21

Table 7
Production and measured reserves of coal in Iran (unit: 1000 t) [44].

Location	Measured reserved	Production	Type of coal
Azarbayjane Sharghi	1356.3	1.3	Thermal coal
Tehran	48.8	–	Coking coal
Khorazan Razavi	295.4	16.1	Coking coal
Khorazan Shomail	60.0	–	Coking coal
Semnan	16335.6	376.5	Coking coal, thermal coal
Kerman	81569.0	954.5	Coking coal, thermal coal
Golestan	17890.7	322	Coking coal, thermal coal
Gilan	4000.0	6.9	Coking coal, thermal coal
Mazandaran	138957.3	224.8	Coking coal, thermal coal
Yazd	560172.1	833.5	Coking coal, thermal coal
Total	1085793.3	2735.6	

Table 8
Capacity of installed hydropower stations in Iran [44].

Location	Number of power station	Capacity (MW)
Azarbayjan Sharghi	1	22
Azarbayjan Gharbi	2	19
Ardebil	1	0.054
Esfehan	2	58.3
Tehran	4	268.5
Khaharmahalo Bakhtiyari	1	39.3
Khorsan	2	0.09
Khuzestan	6	6995
Fars	3	112.25
Kerman	1	32.4
Kohkelooye va booyer Ahmad	6	16.8
Gilan	4	87.71
Lorestan	3	1.63
Mazandaran	3	1.085
Markazi	2	15.6
Hamedan	1	2.8
Total	42	7672.5

Table 9
The situation of wind power stations in Iran [44].

Location	Number of power station	Capacity (MW)
Gilan	111	61,180
Khorasan	45	28,640
Azarbayjane Sharghi	1	10
Total	157	89,930

are 954.5 and 833.4 thousand tons respectively. In fact, these two mines produce about 65.4% of total production of coal in Iran [44].

The measured coal reserves in Iran are 1085.79 million tons which includes 785.20 million tons coking coal and 300.59 million tons thermal coal as presented in Table 7 [44].

The total coal reserve in Iran including measured, indicated and inferred is estimated about 17 billion tons [43]. The consumption of coal has decreased from 1.58 million tons in 2001 to 1.03 million

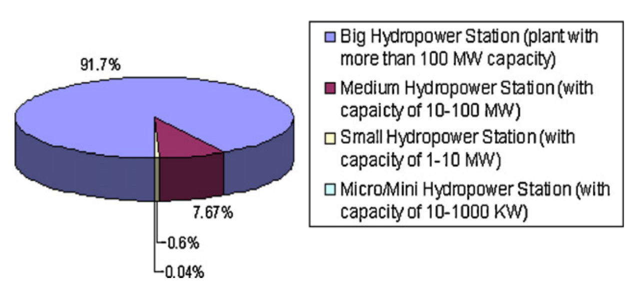


Fig. 7. Contribution of each kinds of hydropower station in electricity generation in Iran [44].

Table 10
The amount of electricity generation by suing solar in Iran (unit: KWh) [44].

Year	Hybrid 6 kW	Photovoltaic 30 kW	Darbid Yaz power station	Sarkavire Semnan power station	Total
2001	–	–	14,100	96,000	110,100
2002	1500	22,000	11,100	14,500	49,100
2003	2200	45,000	10,800	63,450	121,450
2004	3000	45,000	8900	83,300	140,200
2005	–	10,000	18,000	25,000	53,000
2006	–	42,000	17,000	20,000	79,000
2007	–	32,000	15,000	24,000	71,000
2008	–	35,000	19,000	21,000	75,000

tons in 2008. Coal is only used in cement and iron plants in Iran and it has not utilized for electric power generation yet [44].

3.4. Hydropower

Iran is quite advance in constructing hydro dams. Hydro dams are constructed for many purposes such as irrigation, water supply, flood control and electrical power generation which are all related to social-economic development. Beside generating a large amount of electricity, hydropower produces negligible amount of greenhouse gas [48].

There are 42 active hydro power stations with a total capacity of about 7672.5 MW in Iran and some hydropower stations with a total capacity of 6650.1 MW are still being constructed. The number of large hydropower plants (plant with more than 1000 MW capacity) is six and these plants contribute 91.7% of total hydropower plants in Iran as shown in Fig. 7 [48]. The total capacity of installed hydropower stations in Iran is 7672.5 MW as shown in Table 8 [44].

Iran has planned to increase capacity of hydropower stations to 30,000 MW in the near future and the biggest hydroelectric project is in Chaharmahalo bakhtiary with a total capacity of 1342.50 MW [44]. Many countries have built small and mini hydropower stations recently [49], however the contribution of small and mini hydropower stations in energy needs in Iran is very low as shown in Fig. 7.

4. Renewable energy

Renewable energy is defined as an energy that can be produced from natural processes and does not include exhaustible energy resource like fossil fuels and uranium. It is estimated that the contribution of renewable energy in power generation and transport fuels in the world will be 29% and 7% respectively by 2030 [50]. Wind, solar, geothermal and biomass are the kinds of renewable energy that can be utilized in Iran.

4.1. Wind

During past years wind energy has been attractive to many researchers and the amount of generated power by utilizing wind energy has been increased in many countries [51–54]. The main wind power station in Iran is Manjil that is located in southwest of Caspian sea. The capacity of this power station is about 61,180 kW in 2008 [44]. The other wind power stations in Iran are Binalood, Ventiz Dizbad, Sahande Tabriz with capacity of 28,640 kW, 260 kW, 10 kW respectively. Table 9 shows the situation of wind power stations in Iran [44].

The capacity of installed wind power stations has risen from 10,800 kW in 2001 to 89,830 kW in 2008 as shown in Fig. 8. Since Iran has many windy areas, it has great potential of installing wind turbines [55].

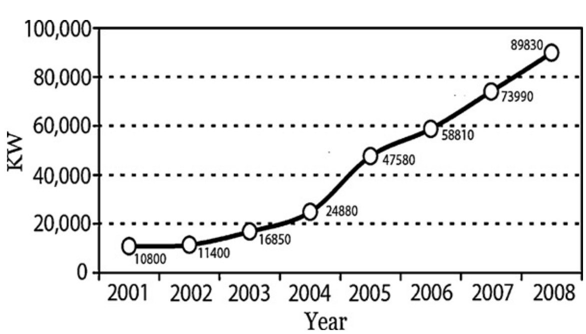


Fig. 8. The capacity of installed wind power stations in Iran [44].

4.2. Biomass

Biomass is one of the most common renewable energy resources in the world with a high potential to contribute to the energy requirements of developed and developing countries [56]. Forest woods and wastes, agricultural products and wastes are some types of biomass energy resources but nowadays they are not the only useful biomass resources. Biomass also includes a wide range of materials such as solid and liquid domestic and industrial wastes. Among all types of renewable energy, biomass is only one which can be used for producing every three kinds of liquid, solid and gas fuels. Many researches have been conducted to apply this kind of renewable energy as a for transportation fuel [10,57–62]. The only common type of biomass energy in Iran is wood [44]. The amount of total land area in Iran is about 162.2 million ha which includes 10.5% under forest and 52.3% under pasture and agricultural. The total amount of forest products which are used as energy generation was around 937,730 m^3 in 2008 [44]. The country also plans to install three biomass station in Shiraz, Mashhad and Saveh with capacity of 1060 kW, 650 kW and 600 kW respectively [43].

4.3. Solar

Nowadays solar energy has become more popular than before as an energy supplier in the world due to efficiency improvement of solar panel [63,64]. Many countries have investigated in utilizing solar energy. They are going to use this kind of renewable energy in many different fields and many researches have been done for this purpose [65–68]. Iran has high potential for using solar energy, due to geographical position. The solar energy in the country varies from 2.8 kWh/m^2 in day in the north to 5.4 kWh/m^2 in day in the south [43]. The sunshine hours is estimated 2800 h per year [69]. The average of sunshine hours per year is 3200 in the central part of Iran due to hot and dry climate [69,70]. Therefore, solar energy can be largely utilized for electricity generation in the country.

Table 10 shows the amount of electricity generation by using solar energy from 2001 to 2008 [44]. Also, there are some operative photovoltaic power stations with capacity of 150 kW currently operated in Iran.

Table 11
Capacity of geothermal power stations in Iran [44].

Geothermal power station	Capacity (MW)	Energy production per year (million KWh)
Main power station of Meshkin Shahr	55	370
Package Meshkin Shahr power generation	3–5	40

4.4. Geothermal

Consider to location of Iran that is on the geothermal belt, Iran has high geothermal energy potential. It is estimated that there is at least 31,000 km^2 area in Iran which is suitable for utilizing geothermal energy. The main geothermal power station in Iran is located in Meshkin Shahr with capacity of 55 MW as shown in Table 11 [44].

5. Conclusion

Iranian energy sector largely depends on the crude oil and natural gas. Due to developing and industrialization the final energy consumption has risen in the past decade in Iran. Based on country development, it is expected that the contribution of final energy consumption in the industrial sector will increase rapidly, while it decreases in the residential sector will decrease slowly due to depleting of fossil fuels reserves and adverse of greenhouse gas emission on climate, therefore the using of sustainable and renewable energy resources is unavoidable in the near future. Although Iran has plans to extend utilizing renewable energy, however the contribution of renewable energy in power generation in Iran is only around 1%. Since the country has many windy areas and at least 2800 h per year sunshine hours, hence it has high potential for utilizing of wind and solar energy and it can be one of major contributors of renewable energy in the country. Noting to the potential of using renewable and sustainable energy resources, Iran must pay more attention to the renewable energy utilization. Many efforts have been done to promote the use of renewable energy, but all the potential has not been used yet. The government should plan to utilize all the potential of energy resources in order to achieve the secure and environmentally sustainable energy resources.

Acknowledgements

The authors would like to acknowledge for the Ministry of Higher Education of Malaysia and The University of Malaya, Kuala Lumpur, Malaysia for the financial support under UM.C/HIR/MOHE/ENG/15 (D000015-16001).

References

[1] BP statistical review of world energy June 2008. London: British Petroleum; 2008.
[2] International Energy Agency (IEA); 2010.
[3] Fadai D. Utilization of renewable energy sources for power generation in Iran. Renew Sustain Energy Rev 2007;11(1):173–81.
[4] Mohammadnejad M, Ghazvini M, Javadi FS, Saidur R. Estimating the exergy efficiency of engine using nanolubricants. Energy Educ Sci Technol Part A: Energy Sci Res 2011;27(2):447–54.
[5] Saidur R, Atabani AE, Mekhilef S. A review on electrical and thermal energy for industries. Renew Sustain Energy Rev 2011.
[6] Abdelaziz E, Saidur R, Mekhilef S. A review on energy saving strategies in industrial sector. Renew Sustain Energy Rev 2010;15(1):150–68.
[7] Saidur R, Leong KY. Application and challenges of nanotechnology. Renew Sustain Energy Rev 2011;15(3):1646–68.
[8] Husnawan M, Masjuki H, Mahlia T, Saifullah M. Thermal analysis of cylinder head carbon deposits from single cylinder diesel engine fueled by palm oil–diesel fuel emulsions. Appl Energy 2009;86(10):2107–13.
[9] Ong HC, Mahlia TMI, Masjuki HH. A review on energy scenario and sustainable energy in Malaysia. Renew Sustain Energy Rev 2011;15(1):639–47.
[10] Jayed M, Masjuki H, Saidur R, Kalam M, Jahirul M. Environmental aspects and challenges of oilseed produced biodiesel in Southeast Asia. Renew Sustain Energy Rev 2009;13(9):2452–62.
[11] Mazandarani A, Mahlia TMI, Chong WT, Moghavvemi M. A review on the pattern of electricity generation and emission in Iran from 1967 to 2008. Renew Sustain Energy Rev 2011;14(7):1814–29.
[12] Saidur R, Masjuki HH, Mahlia TMI. Labeling design effort for household refrigerator-freezers in Malaysia. Energy Policy 2005;33(5):611–8.
[13] Taufiq BN, Masjuki HH, Mahlia TMI, Saidur R, Faizul MS, Niza Mohamad E. Second law analysis for optimal thermal design of radial fin geometry by convection. Appl Therm Eng 2007;27(8–9):1363–70.
[14] The World Bank Group; 2011.
[15] Husnawan M, Masjuki HH, Mahlia TMI, Saifullah MG. Thermal analysis of cylinder head carbon deposits from single cylinder diesel engine fueled by palm oil–diesel fuel emulsions. Appl Energy 2009;86(10):2107–13.
[16] Mahlia TMI, Abdulmuin MZ, Alamsyah TMI, Mukhlishien D. An alternative energy source from palm wastes industry for Malaysia and Indonesia. Energy Convers Manage 2001;42(18):2109–18.
[17] Mahlia TMI, Abdulmuin MZ, Alamsyah TMI, Mukhlishien D. Dynamic modeling and simulation of a palm wastes boiler. Renew Energy 2003;28(8):1235–56.
[18] Mahlia TMI, Chan PL. Life cycle cost analysis of fuel cell based cogeneration system for residential application in Malaysia. Renew Sustain Energy Rev 2011;15(1):416–26.
[19] Mahlia TMI, Iqbal A. Cost benefits analysis and emission reductions of optimum thickness and air gaps for selected insulation materials for building walls in Maldives. Energy 2010;35(5):2242–50.
[20] Mahlia TMI, Masjuki HH, Saidur R, Amalina MA. Cost-benefit analysis of implementing minimum energy efficiency standards for household refrigerator-freezers in Malaysia. Energy Policy 2004;32(16):1819–24.
[21] Mahlia TMI, Masjuki HH, Saidur R, Choudhury IA, NoorLeha AR. Projected electricity savings from implementing minimum energy efficiency standard for household refrigerators in Malaysia. Energy 2003;28(7):751–4.
[22] Mahlia TMI, Masjuki HH, Taha FM, Rahim NA, Saidur R. Energy labeling for electric fans in Malaysia. Energy Policy 2005;33(1):63–8.
[23] Mahlia TMI, Razak HA, Nursahida MA. Life cycle cost analysis and payback period of lighting retrofit at the University of Malaya. Renew Sustain Energy Rev 2011;15(2):1125–32.
[24] Mahlia TMI, Said MFM, Masjuki HH, Tamjis MR. Cost-benefit analysis and emission reduction of lighting retrofits in residential sector. Energy Build 2005;37(6):573–8.
[25] Mahlia TMI, Saidur R, Memon LA, Zulkifli NWM, Masjuki HH. A review on fuel economy standard for motor vehicles with the implementation possibilities in Malaysia. Renew Sustain Energy Rev 2011;14(9):3092–9.
[26] Mahlia TMI, Taufiq BN, Ismail, Masjuki HH. Correlation between thermal conductivity and the thickness of selected insulation materials for building wall. Energy Build 2007;39(2):182–7.
[27] Mahlia TMI, Yanti PAA. Cost efficiency analysis and emission reduction by implementation of energy efficiency standards for electric motors. J Cleaner Prod 2010;18(4):365–74.
[28] Saidur R, Mahlia TMI. Energy, economic and environmental benefits of using high-efficiency motors to replace standard motors for the Malaysian industries. Energy Policy 2010;38(8):4617–25.
[29] Baños R, Manzano-Agugliaro F, Montoya FG, Gil C, Alcayde A, Gómez J. Optimization methods applied to renewable and sustainable energy: a review. Renew Sustain Energy Rev 2011;15(4):1753–66.
[30] de Souza ACC, Silveira JL. Hydrogen production utilizing glycerol from renewable feedstocks—the case of Brazil. Renew Sustain Energy Rev 2011;15(4):1835–50.
[31] Gastli A, Charabi Y. Solar water heating initiative in Oman energy saving and carbon credits. Renew Sustain Energy Rev 2011;15(4):1851–6.
[32] Kumar A, Sharma S. Potential non-edible oil resources as biodiesel feedstock: an Indian perspective. Renew Sustain Energy Rev 2011;15(4):1791–800.
[33] Nautiyal H, Singal SK, Varun, Sharma A. Small hydropower for sustainable energy development in India. Renew Sustain Energy Rev 2011;15(4):2021–7.
[34] Ahmed AS. Analysis of electrical power form the wind farm sitting on the Nile River of Aswan, Egypt. Renew Sustain Energy Rev 2011;15(3):1637–45.
[35] Chang IS, Zhao J, Yin X, Wu J, Jia Z, Wang L. Comprehensive utilizations of biogas in Inner Mongolia, China. Renew Sustain Energy Rev 2011;15(3):1442–53.
[36] Amigun B, Musango JK, Stafford W. Biofuels and sustainability in Africa. Renew Sustain Energy Rev 2011;15(2):1360–72.
[37] Chellali F, Khellaf A, Belouchrani A, Recioui A. A contribution in the actualization of wind map of Algeria. Renew Sustain Energy Rev 2011;15(2):993–1002.
[38] Misra RD, Murthy MS. Jatropa—the future fuel of India. Renew Sustain Energy Rev 2011;15(2):1350–9.
[39] Safari B. Modeling wind speed and wind power distributions in Rwanda. Renew Sustain Energy Rev 2011;15(2):925–35.
[40] Sorapipatana C, Yoosin S. Life cycle cost of ethanol production from cassava in Thailand. Renew Sustain Energy Rev 2011;15(2):1343–9.

[41] Statistical pocketbook of Islamic Republic of Iran. Tehran, Iran: Statistical Center of Iran; 2010.
[42] Iran central bank reports bulletin. Tehran, Iran: Central Bank of Iran; 2010.
[43] Hydrocarbon balance 2008. Tehran: Iran Institute for International Energy Studies (IIES); 2010.
[44] Energy balance 2008. Tehran: Iran Ministry of Power; 2010.
[45] Renewable Energy Research and Technology Bureau. New Energy Source Organization (SUNA); 2010.
[46] Dincer I. Renewable energy and sustainable development: a crucial review. Renew Sustain Energy Rev 2000;4(2):157–75.
[47] Annual statistical bulletin. Organization of the Petroleum Exporting Countries (OPEC); 2009.
[48] Bartle A. Hydropower potential and development activities. Energy Policy 2002;30(14):1231–9.
[49] Renewables 2009 global status report. Paris, France: Renewable Energy Policy Network for the 21st Century; 2009.
[50] World Energy Outlook (WEO). Alternative policy scenario. International Energy Agency (IEA); 2007.
[51] Islam M, Saidur R, Rahim N. Assessment of wind energy potentiality at Kudat and Labuan, Malaysia using Weibull distribution function. Energy 2011.
[52] Saidur R, Rahim NA, Solangi KH, Islam MR. Environmental impact of wind energy. Renew Sustain Energy Rev 2010.
[53] World wind energy report 2009. Germany: World Wind Energy Association (WWEA); 2009.
[54] Losique J. Wind and water power program. USA; 2010.
[55] Energy in Iran 2008. Tehran: Power & Energy Planning Department – Ministry of Energy; 2010.
[56] Demirbas MF, Balat M, Balat H. Potential contribution of biomass to the sustainable energy development. Energy Convers Manage 2009;50(7): 1746–60.
[57] Renewable energy as a sustainable fuels. Tehran: Institute for International Energy studies – Petroleum Ministry of Iran; 2010.
[58] Agarwal AK. Biofuels (alcohols and biodiesel) applications as fuels for internal combustion engines. Prog Energy Combust Sci 2007;33(3): 233–71.
[59] Fulton L. Biofuels for transport: an international perspective. In: Proceedings of assessing the biofuels option. 2005.
[60] Sharma Y, Singh B. Development of biodiesel: current scenario. Renew Sustain Energy Rev 2009;13(6–7):1646–51.
[61] Husnawan M, Masjuki H, Mahlia T, Mekhilef S, Saifullah M. Use of post flame metal-based and oxygenated additive combination for biodiesel–diesel blends.
[62] Mekhilef S, Siga S, Saidur R. A review on palm oil biodiesel as a source of renewable fuel. Renew Sustain Energy Rev 2011;15(4):1937–49.
[63] Jacobson MZ. Review of solutions to global warming, air pollution, and energy security. Energy Environ Sci 2009;2(2):148–73.
[64] Solangi KH, Islam MR, Saidur R, Rahim NA, Fayaz H. A review on global solar energy policy. Renew Sustain Energy Rev 2011.
[65] Islam MR, Saidur R, Rahim NA, Solangi KH. Usage of solar energy and its status in Malaysia. Eng e-Trans 2010:6–10.
[66] Saidur R, Masjuki HH, Hasanuzzaman M. Performance of an improved solar car ventilator. Int J Mech Mater Eng 2009;4(1):24–34.
[67] Mekhilef S, Saidur R, Safari A. A review on solar energy use in industries. Renew Sustain Energy Rev 2011;15(4):1777–90.
[68] Saidur R, Masjuki H, Hasanuzzaman M, Mahlia T, Tan C, Ooi J, Yoon P. Performance investigation of a solar powered thermoelectric refrigerator. Int J Mech Mater Eng 2008;3(1):7–16.
[69] Renewable energy sources. Islamic Republic of Iran: Iranian Atomic Energy Agency (IAEA); 2010.
[70] Renewable energy in Iran. Energy Statistical Review of Iran; 2002. p. 223–39.